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RADIO EMISSION EVOLUTION OF NONSTATIONARY SOURCES IN THE "HEDGEHOG" MODEL

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16. Abstract

Correlations are obtained for numerical calculation of flux F_ν and polarized radiation intensity of a cloud of arbitrary geometry, consisting of ultrarelativistic electrons that dissipate in a radial magnetic field of the nucleus at a random angle ϑ to the observer. It is possible that some of the variable extragalactic objects that were previously described by the Shklovskiy model [1,2] are young formations in the examined model. Radio astronomical observations would permit a determination of the distance to them, age, lifetime, γ, ϑ and Z_{omax}.

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Now one can write the density of the complete received flux F_ν and intensity $I_\nu^{(m)}$ for the random cloud of fairly small angular dimensions in the following form ($\tilde{\rho}_K \equiv \tau_K / \tau_{omin}$):

$$F_\nu = \left(\frac{\tau_{omin}}{R}\right)^2 \cdot \iint\limits_{(\sigma)} \left(I_\nu^{(1)} + I_\nu^{(2)}\right) \cdot f_\tau \, d\rho_o \, d\varphi \quad , \qquad (20)$$

where $I_\nu^{(m)}$ is the solution to the transport equation

$$\frac{dI_\nu^{(m)}}{f_z \, d\vartheta} = -\tilde{\mu}_\nu^{(m)} \cdot I_\nu^{(m)} + \tilde{\varepsilon}_\nu^{(m)} \quad , \qquad (21)$$

whereupon $f_z \, d\vartheta = dz$, $f_\tau \, d\rho_o = \tilde{\rho}_K \, d\tilde{\rho}_K$, and by using $z = \tau_K \cdot ctg\,\vartheta$ and (11), we obtain

$$f_z = -\tau_{omin} \cdot \tilde{\rho}_K / \sin^2 \vartheta \quad , \qquad (22)$$

$$f_\tau = \rho_o \left[1 + C_o \left(\frac{\tilde{T}}{\rho_o} - C_o\right)\right] \quad , \qquad (23)$$

$$\tilde{\rho}_K = \rho_o \sqrt{1 - \left(\frac{\tilde{T}}{\rho_o} - C_o\right)^2} \qquad (24)$$

The limits of integrating for ϑ and φ are defined by the geometry of the /14 specific cloud and the region for existence of the corresponding waves, according to the data of Figure 2, and according to ρ_o—constant: from $\rho_o = 1$ to $\rho_o = \tau_{omax}/\tau_{omin}$, where $\tau_{omax} \equiv \tau_{omin} + \Delta\tau_o$—maximum τ_o of the cloud. Here it is considered that $d\tau_K / d\tau_o > 0$,

ANNOTATION

Correlations are obtained for numerical calculation of flux F_ν and polarized radiation intensity of a cloud of arbitrary geometry, consisting of ultrarelativistic electrons that dissipate in a radial magnetic field of the nucleus at a random angle ϑ to the observer. It is shown that there exists a maximum observed distance z_{omax} of the cloud points from the center of the nucleus in the picture plane, while the observed cloud lifetime $\tau_{\varkappa} \lessdot 2 \cdot z_{omax}/c$ where c--speed of light; whereupon, $\tau_{\varkappa}$ is defined as the radiation cutoff as a consequence of the evolution of pitch-angles or absorption of electrons by the nucleus. Results are obtained in an analytical and numerical form for the case of a short jet of electrons. Here, in contrast to other models of variable sources: 1) the time dependence F_ν with assigned ϑ and frequency ν has a monotonic drop or rise, on which several (up to 3) flares can be superimposed; 2) the jet spectrum F_ν from ν is shifted with time downwards and to the left, then upwards and to the right; 3) sub-light and super-light seeming velocities of movement and expansion of the cloud are possible; 4) the evolution of the observed spectra can be explained with a typical exponent for the energy spectrum of electrons δ=2-3. It is possible that some of the variable extragalactic objects that were previously described by the Shklovskiy model [1, 2] are young formations in the examined model. Radio astronomical observations would permit a determination of the distance to them, age, lifetime, γ , ϑ and z_{omax}.

RADIO EMISSION EVOLUTION OF NONSTATIONARY SOURCES IN THE "HEDGEHOG" MODEL

By. Yu. A. Kovalev and V. P. Mikhaylutsa

1. Introduction /5*

As far as we know, the general statement of the task was given for the first time by N. S. Kardashev [3] in a discussion of the most probable phenomenological model of quasars, and consisted of the need to formulate a theory of emission of clouds that "are dispersed" in a radio magnetic field of quasar nucleus.

Different particular cases of this task and substantiations for the model have been examined in [4, 5] and our unpublished degree (Leningrad State University) and course (Moscow State University) work in 1970. This work is a further development and generalization of the questions that we previously examined, and is distinguished from [4, 5] by a significantly more general statement of the task. Here we attempted to make a critical consideration of the results of the listed publications that are important for the covered questions, and if possible, to avoid new errors.**

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*Numbers in margin indicate pagination in original foreign text.

**The main common shortcoming of our work is the absence of a proper consideration for the delay factor. In publication [4], special attention was given to this effect. however, as shown in [5], the method of examination was incorrect. Finally, publication [5] has found a path that is correct in our opinion for obtaining the delay factor, but unfortunately, in turn miscalculations were permitted that significantly restrict the area of correctness of the obtained solution.

We think that the examined model can refer not only to processes in the active nuclei of galaxies and quasars, but will also be useful in an analysis of phenomena in those galactic sources whose activity has a "flare nature," while the movement and emission of particles are defined not by the natural magnetic field of the cloud, but the external, i.e., the field of the star. It is possible that the conditions close to this are fulfilled during flares of magnetic stars and certain flashes [6] of solar radio emission. Therefore, in the statement of the task below, by nucleus we do not mandatorily mean the quasar nucleus, but in general, a certain plasma magnetic body whose field determines the cloud evolution. /6

2. Statement of Task. Initial Correlations

Assume that at the beginning moment in time t'_0, as a result of a certain process* the arbitrary geometry was formed of a cloud of ultrarelativistic electrons that are dissipated in time $t'>t'_0$ in a radio magnetic field of a certain nucleus. The radiation is recorded by an observer located in direction $\vec{l}$ at random angle ϑ_N to the axis z' of the cloud at a fixed distance R from the nucleus of radius r_n, at moment in time $t = t' + R_{clo}(t')/c$, where R_{clo} (t') is the distance from the cloud to the observer, and c is the speed of light (Figure 1).

During the lifetime of the cloud the following conditions are assumed to be fulfilled. The density of the magnetic field energy is much greater than the density of the electron energy. The initial distribution of electrons in the cloud is uniform, and according to velocities--isotropic. When cloud electrons enter the

*For example, during discharge of the cloud from the nucleus (including during simultaneous compression of the latter) or during "spilling" of the particles from the area of local heterogeneity of the magnetic field.

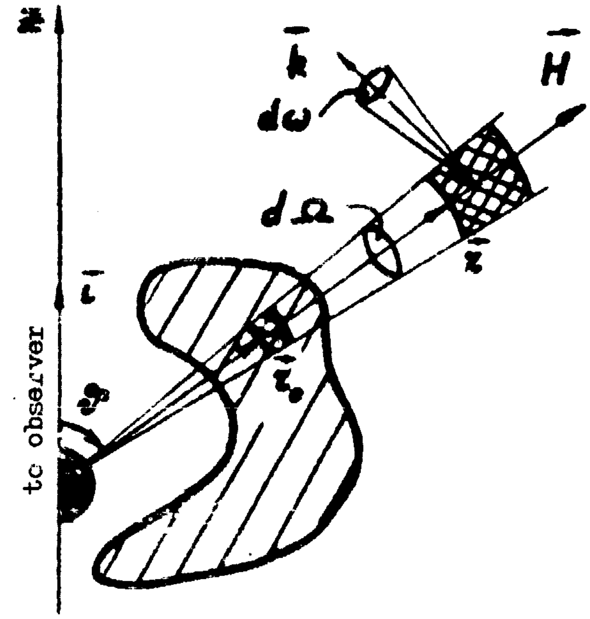

Figure 1. Geometry of Model
Area of nucleus is blackened. Sections of cloud at beginning moment t'_0 and isolated volume element at moments t'_0 and $t' > t'_0$ are hatched.

region of the nucleus they are completely absorbed. We will ignore all the losses except the synchrotron, as well as the change in the energy spectrum of the emitting electrons. The following are preserved: 1) adiabatic invariant, 2) flux in the magnetic field intensity vector $\vec{H}$ through the surface encompassing the nucleus, 3) number of electrons $dN(E, \vec{k}, \vec{r}, t')$ with energies from E to E+dE, that at the initial moment t'_0 are located in the element of spatial volume dV_0 around $\vec{r}_0$, and /7
whose velocity vectors lie in limits of the solid angle $d\omega_0$ near the direction $\vec{k}_0$.

It is required that the observed changes be found in the spectral characteristics of emission and the geometry of the cloud in the process of its evolution.

The solution to the task uses spherical r, ϑ, φ and cylindrical r_k, z, φ coordinates ($r_k = r \times \sin\vartheta$) with beginning at the nucleus center and axis z in the direction of the observer. It is assumed, that the variable amounts with zero lower

indices correspond to their beginning values.

Within the cloud at moment t'_0 we will select the volume element $dV = r^2 dr\, d\Omega$. The electrons that belong to it are moved with natural pitch angles ψ in the magnetic field whose lines of force are contained in the limits $d\Omega = \sin\vartheta\, d\vartheta\, d\varphi$. We will examine the emissions of these electrons in direction of the observer $\vec{i}$ (see Figure 1). In this case known correlations can be used for the spectral emission coefficients ε_ν and reabsorption μ_ν (see, for example, [7, 8]), that we can write in the following form with regard for the delay factor for a nonstationary region:

$$\varepsilon_\nu^{(m)} = A^{(m)}(\gamma)\cdot \nu^{\frac{1-\gamma}{2}} \cdot (H \sin\vartheta)^{\frac{\gamma+1}{2}} \cdot K(\vec{i}, \vec{r}, t') \cdot |\partial t'/\partial t| , \qquad (1)$$

$$\mu_\nu^{(m)} = B^{(m)}(\gamma)\cdot \nu^{-\frac{\gamma+4}{2}} \cdot (H \sin\vartheta)^{\frac{\gamma+2}{2}} \cdot K(\vec{i}, \vec{r}, t') \cdot |\partial t'/\partial t| . \qquad (2)$$

Here the index (m) takes into consideration the wave polarization: m=1 for components of the electrical vector of a wave directed along the vector $\vec{H}\sin\vartheta$, m=2 for its orthogonal component. $A^{(m)}(\gamma)$ and $B^{(m)}(\gamma)$ are known functions for the index of the electron energy spectrum γ, while the delay factor looks like [9]:

$$\frac{\partial t'}{\partial t} = \left(1 - \frac{\partial r}{\partial t'} \cdot \frac{\cos\vartheta}{c}\right)^{-1}. \qquad (3)$$

It follows directly from the assigned conditions for preservation:

$$H = H_0 (r/r_0)^{-2} \equiv H_0 \rho^{-2}, \qquad (4)$$

$$[illegible] = \sin\psi_0 ; \qquad (5)$$

$$dN(E, \vec{k}, \vec{r}, t') = K(\vec{k}, \vec{r}, t') \cdot E^{-\gamma} dE\, dV\, d\omega = dN(E_0, \vec{k}_0, \vec{r}_0, t'_0). \qquad (6)$$ /8

It is easy to see that in the framework of the set task the volume element evolution can be schematically described by the movement of several spatial "waves" of electrons: electrons with initial pitch angles $\psi_o < \pi/2$ move from the nucleus (we designate this wave "SW"--"straight wave"), while the electrons with $\psi_o > \pi/2$-- move at first towards the nucleus (forming "IW"--"inverse wave"), then either they are reflected from the intensified magnetic field (then a "RW"--"reflected wave" appears), or, if the point of reflection lies under the nucleus surface, are absorbed by the nucleus.* We will use these designations for the electron waves below for brevity.

3. Evolution of Characteristics of Volume Elements, Emitted in an Arbitrary Direction, for SW, IW and RW

We will examine the movement of individual electrons according to $\vec{z}$. The time necessary to traverse the path from z_o to z (here the current pitch angle ψ' is changed from ψ_o to ψ), can be obtained from (see, for example [5]): $\Delta t = t - t_o = \int dz/c \times \cos\psi'$, by integrating in the limits from z_o to z. Taking into consideration (5), after integration we will have: $T' = \rho \cdot \cos\psi - \cos\psi_o$, where

$T' \equiv \Delta t' \cdot c/z_o$; $\psi_o < \pi/2$, $\psi < \pi/2$, $\rho \geq 1$ --for SW; $\psi_o > \pi/2$, $\psi > \pi/2$, $\rho \leq 1$ --for IW; $\psi_o > \pi/2$, $\psi < \pi/2$, $\rho > 0$ -- for RW.** We obtain from (7) with regard for (5):

$$\rho = T'\cos\psi \pm \sqrt{1 - (T'\sin\psi)^2} \equiv T'\cos\psi \pm Q , \qquad (6)$$

*Of course for different elements of the cloud volume that are emitted at the given moment of time in the direction of the observer, the values ϑ, z_o, H_o, ψ_o, and therefore the phases of evolution also, generally speaking, differ and are determined by the initial geometry of the cloud. This is taken into consideration during the transition to an examination of the emission of the entire cloud in section 4.

**It is possible to prove the correctness of (7) for RW, by using (7) and (5) to find the time $\Delta t'_1$ and $\Delta t'_2$ on the path respectively before the point of reflection and after it, and taking into consideration that $\Delta t'_1 + \Delta t'_2 = \Delta t'$. Absorption by the nucleus will be considered below.

where one should use the upper sign for SW and IW, and for RW the solution is correct not only with the upper, but with $1 \leq T' \leq 1/\sin\psi$—and with the lower sign. Here an interesting property of reflected wave appears—duality: with $T' > 1$ in addition to the previous, electrons with $\psi_0 \approx \pi$ begin to light up; they are reflected from the more internal regions of the field (Figure 2). In accordance with (8) we divide RW into two waves (see Figure 2): RWS (RW-"straight") with upper sign in (8) and RWT (RW-"turned") with lower sign in (8). Further, unless it is stipulated specially, all the correlations will be written for four waves simultaneously, whereby for ambiguous expressions the lower sign will refer to RWT, and the upper to the other waves.

From (8) with ψ=const we obtain $\partial z/\partial t'$, which after substitution in (3), and after assuming $\psi = \vartheta$, yields*:

$$\frac{\partial t'}{\partial t} = \pm \frac{a}{\rho \sin^2 \vartheta} . \qquad (9)$$

By analyzing (5), (7)-(9), one can see that the fulfilled formal transition from fixed ψ_0 to fixed $\psi = \vartheta$ is equivalent to the transition from the motion equation of one electron to the "equation of lighting up" of the system of electrons that are distinguished from each other by the initial pitch angles ψ_0, but which emit in sequence at one angle ϑ from different distances z (due to the different ψ_0 and $\Delta t'$), at those moments when their velocity vectors intersect the direction to the observer. Therefore the rate of such lighting up $\partial z/\partial t'$ can be interpreted /10

*It is easy to be convinced that the delay factor for RWT is negative. Thus, if the model corresponds to actuality, then in the example of RWT we have a natural "time machine" in action; the observer "sees" the events in reverse sequence.

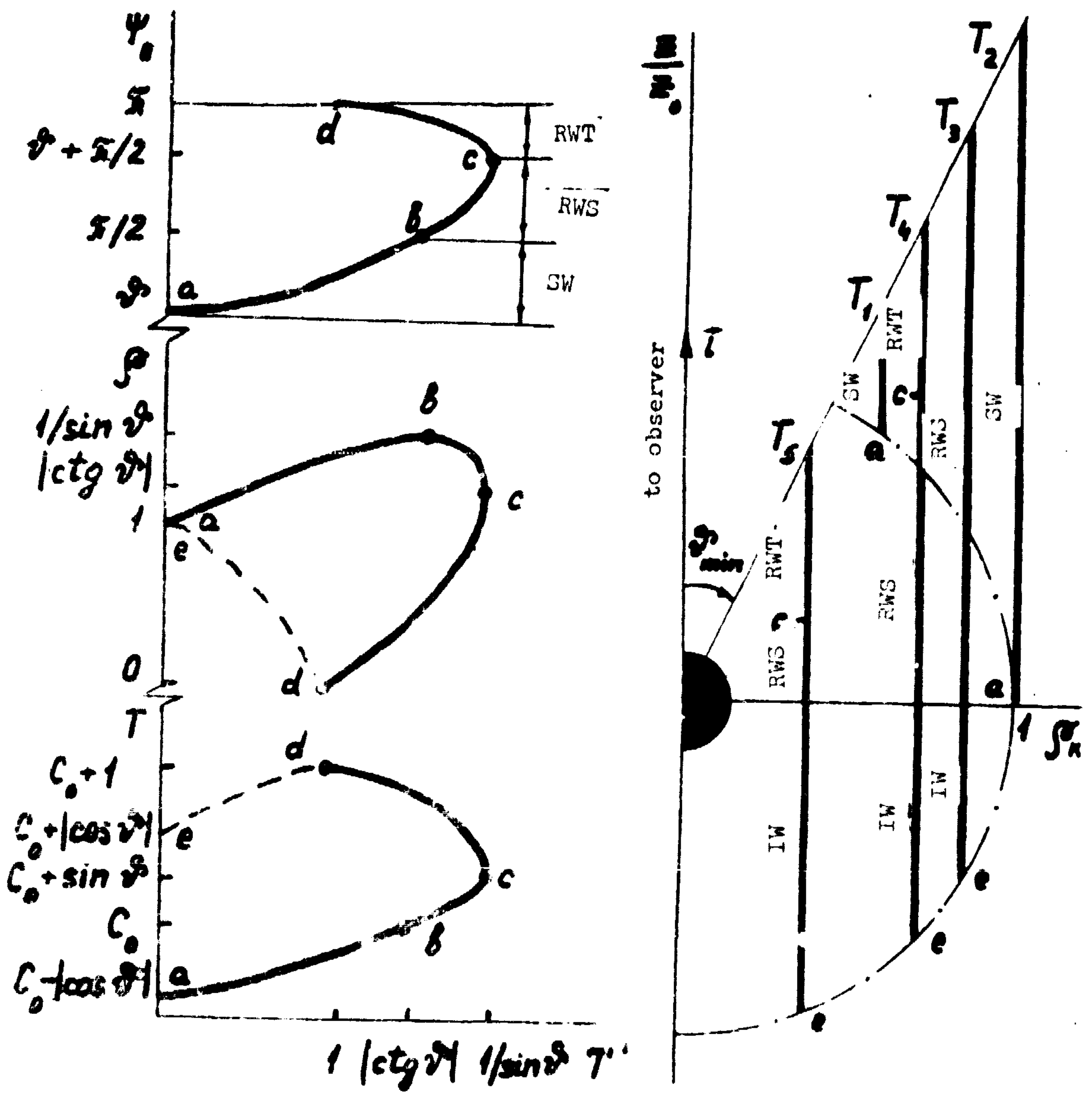

Figure 2. Evolution of Dimensionless Parameters of Task
On the left--beginning pitch angles Ψ_0 and distances ρ from center of nucleus for electron emitting at angle $\psi = \vartheta$ to the magnetic field, depending on the time interval of emission T' and observation T (dotted line indicates the section IW for electrons emitted at angle $\pi - \vartheta$); the coordinates of the noted points are indicated. On the right--paths of integration for transport equation with evolution of officially spherical cloud layer (the greater T corresponds to the greater indices T), the angles of the corresponding points are equal to $\vartheta_a = \arcsin \rho_K$,

the boundary between IW and RWS passes through $\vartheta = \pi/2$.

only formally as the "rate of source movement"* (here $\partial z/\partial t' > c$ is possible, however it does not yet follow from here that the observed velocity $\partial z/\partial t > c$).

By integrating (9) we obtain the link between the segments of observation time $\Delta t = t - t_0$ and emission $\Delta t'$ (Figure 2):

$$T' = (T - C_0) + ctg\,\vartheta \cdot \sqrt{1-(T-C_0)^2}\,, \qquad (10)$$

while after substituting (10) in (8) we will have the motion equation for the volume element (emitted at angle ϑ to $\vec{z}$) depending on the time of the observer:

$$\rho = \sqrt{1-(T-C_0)^2}\,/\sin\vartheta\,. \qquad (11)$$

In (10) and (11) $T = \Delta t \times c/\tau_0$, while C_0 is an integration constant. ORIGINAL PAGE IS OF POOR QUALITY

In order to obtain the electron distribution function, after using (6) and the condition of the task, we write**: /11

$$K(\vec{k},\vec{z},t')\,d\omega\,dV / K(\vec{k}_0,\vec{z}_0,t'_0)\,d\omega_0\,dV_0 = 1\,. \qquad (12)$$

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*This effect was noted for the first time in publication [5], where the case of SW was examined, $\vartheta \ll 1$ and $\rho \gg 1$ (in our terminology). However, the actual rate and the delay factor in [5] were obtained with error that increased with a rise in ρ. Thus in [5] $\partial t'/\partial t = 1/\rho\vartheta^2$ instead of $\partial t'/\partial t = Q/\rho\vartheta^2$ from (9), which is important, since $Q < 1$ with $\rho > 1$, and $Q \ll 1$ with the examined $\rho \gg 1$, whereupon, $Q \to \vartheta$ (due to $T' \to ctg\,\vartheta$ before the cutting off of the SW emission--see Figure 2).

**We do not at all think that the methods for obtaining k, dV and dw proposed here are ideal, however the attempts to find better methods were unsuccessful.

One can find from (7) with regard for (5), by fixing Ψ_0 and $\Delta t'$:

$$d\tau/d\tau_0 = (1 + T'\cos\Psi_0)/\rho \, , \qquad (13)$$

while examining dV, after substituting (13) and transition from Ψ_0 to Ψ, we obtain

$$dV/dV_0 = \rho^2 d\tau/d\tau_0 = \pm Q \cdot \rho^2 \, , \qquad (14)$$

where ρ and Q are assigned (8) for a specific wave. We find $d\Psi/d\Psi_0$, after substituting in (5) $\rho(\Psi_0, T')$ from (7), and after differentiating the obtained expression, considering T'=const. After transformations we will have:

$$d\Psi/d\Psi_0 = (\cos\Psi_0 + T'\sin^2\Psi)/\rho \cdot \cos\Psi = \pm Q/\rho \, , \qquad (15)$$

By using (15) and (5), we obtain:

$$d\omega/d\omega_0 = \sin\Psi d\Psi/\sin\Psi_0 d\Psi_0 = \pm Q/\rho^2 \, . \qquad (16)$$

Finally, (14) and (16) after substitution in (12) and transition to the fixed $\Psi = \vartheta$, yield:

$$K(\bar{k} = \bar{\iota}, \bar{\tau}, t')/K(\bar{k}_0 = \bar{\iota}, \bar{\tau}_0, t'_0) = Q^{-2} \, . \qquad (17)$$

By substituting (4), (9), (17) and (11) in (1) and (2), and by passing further from T' to T, according to (10), we obtain the evolution for the coefficients of emission and absorption depending on the time of the observer. /12

4. Emission of the Electron System in the Cloud

Since equation (11) is correct with any ϑ, then it directly describes the evolution of the initially spherical layer of the cloud (or its parts) that is

emitted in the assigned direction. It is apparent from (11), that the spherical cloud (with center at $\tau = 0$) will be perceived by the observer as a circular cylinder whose diameter and length are evolved, and whose axis coincides with the axis z. Then, when C_o is selected for the condition $\Delta t = 0$ with $\Delta t' = 0$ for SW, which yields

$$C_o = \cos \vartheta_{min}, \qquad (18)$$

where ϑ_{min}--minimum angle in cloud, will be considered to be an additional delay in the signal coming to the observation point from the more distant points of the surface with coordinates $\vartheta > \vartheta_{min}$. Thus, the application of (11) and (18) to all the characteristic spherical layers into which the random cloud can be divided at the beginning moment, will yield the unknown evolution of its geometry.

All the previous correlations were obtained without consideration for the absorbing properties of the nucleus. As one can show, its effect is felt only when the following condition is not fulfilled for IW and RW:

$$\tau \cdot \sin \vartheta \geq \tau_{я}. \qquad (19)$$

At the cloud point with coordinates τ, and ϑ, where (19) is not fulfilled, "holes" will be observed for IW and RW due to the absorption of the corresponding electrons by the nucleus.

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In order to take into consideration that elements of the volume with different values of the beginning parameters are emitted along the visual beam, first of all we replace $\varepsilon_\nu^{(m)}$ and $\mu_\nu^{(m)}$ by $\tilde{\varepsilon}_\nu^{(m)}$ and $\tilde{\mu}_\nu^{(m)}$, that were obtained by substituting in (1) and (2) the correlations $T = \tilde{T}/\rho_o$, $H_o = \tilde{H}_o/\rho_o^2$, $\rho = \tilde{\rho}/\rho_o$, /13

where $\rho_o = \tau_o/\tau_{omin}$, while τ_{omin} is the minimum τ_o of the cloud, at the same time reducing everything to a unified point of reading--τ_{omin}.

i.e., the cloud layers move without "overtaking" each other. It was possible to write the transport equation of polarized emission in a simple form (21) thanks to the "convenient" geometry of the field (see [7, 8]).

Thus, the evolution of the source spectrum is obtained by multiple computation (20) and (21) with the assigned spacing according to Δt and ν. Here, for each Δt and ν equation (21), applied to the corresponding waves in sequence for the visual beam with regard for (19) produces the distribution of polarized intensity according to σ (i.e., the "visible" structure of the source).

We will examine the radiation of the "jet" of electrons moving at a random angle to the observer ($(\tau_n \ll \tau_0, \Delta\tau_0 \ll \tau_0, \Delta\Omega \ll 1,$ ϑ —any). For such a particular case of the task the final results can be given in an analytical form. In fact, we have:

$$F(\nu, \rho, \vartheta) \approx I \cdot \Omega_N$$

where Ω_N is the observed solid angle of the jet. By norming (25) for $F(\nu_{mo}, 1, \vartheta)$, where ν_{mo} is the frequency at which F reached the maximum value with $\rho=1$, by using (11), we obtain (see also [2, 8]):

$$\frac{F(\nu, \rho, \vartheta)}{F(\nu_{mo}, 1, \vartheta)} \approx \frac{I}{I_{mo}} \cdot \frac{\Omega_N}{\Omega_{No}} \qquad (26)$$

where $$\frac{\Omega_N}{\Omega_{No}} \approx \frac{z_K \cdot \Delta z_K \cdot \Delta\Psi_0}{z_{Ko} \cdot \Delta z_{Ko} \cdot \Delta\Psi_0} \approx 1 + T \cdot \frac{\cos\vartheta}{\sin^2\vartheta} , \qquad (27)$$ /15

$$\frac{I}{I_{mo}} \equiv \frac{I(\nu, \rho, \vartheta)}{I(\nu_{mo}, 1, \vartheta)} \approx \left(\frac{\nu}{\nu_{mo}}\right)^{5/2} \cdot \rho \cdot \frac{1-\exp(-\tau)}{1-\exp(-\tau_m)} , \qquad (28)$$

$$\tau = \tau_m \cdot (\nu/\nu_{mo})^{-\frac{\gamma+4}{2}} \cdot Q^{-1} \cdot \rho^{-(\gamma+2)} , \qquad (29)$$

whereupon, τ_m is the solution to the equation

$$exp(\tau_m) = 1 + \left(\frac{\gamma+4}{5}\right) \cdot \tau_m \quad , \tag{30}$$

and from (8) and (7) Q is obtained:

$$\pm Q = \rho \cdot \sin^2 \vartheta - (T - \cos \vartheta) \cdot \cos \vartheta \; . \tag{31}$$

It follows from (26)-(29)

$$F(\nu_m, \rho_m, \vartheta) / F(\nu_{m0}, 1, \vartheta) = (\nu_m / \nu_{m0})^{5/2} \cdot \rho_m \cdot \Omega_N / \Omega_{N0}, \tag{32}$$

$$\nu_m / \nu_{m0} = \rho_m^{-2(\gamma+2)/(\gamma+4)} \cdot Q^{-2/(\gamma+4)} \quad . \tag{33}$$

Above (27) and (31) were written, assuming for convenience in (11) $C_0 = \cos \vartheta$ (i.e., for each ϑ --its own beginning of time reading).

By using (11), one can obtain the seeming velocities of "movement" v_m and expansion v_e of the emitting jet in the picture plane. For v_m we have

$$v_m(\Delta t, \vartheta) = c \cdot \frac{\cos \vartheta - T}{\sqrt{1 - (T - \cos \vartheta)^2}} \quad . \tag{34}$$

5. Discussion of Chief Results /16

We will note a number of general features that are inherent to a cloud of any geometry that is arbitrarily oriented in relation to the observer.

1. The observed lifetime of the cloud (up to cutoff of emission) $\tau_{\kappa} < 2 \times z_{cmax}/c$ (however, here $\tau_{\kappa}' >> \tau_{\kappa}$ can be).

The basic possibility of an absolute estimate of the maximum distance $r_{\sigma max}$ according to the measured r_{kr} follows.

2. If $r_n < r_{\sigma min}$, then the cloud in the process of evolution is divided into several waves, that can yield a complex visible pattern of components that emerge, develop and disappear. For the observer, the maximum distance of the components in the picture plane from the nucleus center is $r_{kmax} = r_{\sigma max}$. Further, the source either "is extinguished" (this means that $r_n = r_{\sigma min} \approx r_{\sigma max}$), or moves backwards (this means $r_n < r_{\sigma min}$). The site of extinction of the component r_{kr} during movement backwards characterizes r_n : $r_n = r_{kr}$. In the case of a difference in the beginning distribution of velocities from the isotropic, the described pattern can be distorted.

We will examine in more detail the results from analyzing the jet model and will compare them with the primary known characteristics of emission of variable extragalactic sources.

1. The observed above-light velocities of divergence and expansion of the components of certain objects (see, for example, [10]) can be explained in the framework of the examined model. In fact, it follows from (34) that $v_n > c$ for

$$T < [\cos \vartheta - (1/\sqrt{2})] \quad \text{and} \quad T > [\cos \vartheta + (1/\sqrt{2})],$$

while the movement occurs with a delay or acceleration depending on the wave type. It is easy to show that $v_p > c$ is also possible.

2. The relationship $f_m \propto \nu_m^{\alpha}$ observed for many sources where $\alpha \approx 0.6$-1.0 [4] is attained in the model with any ϑ. However, in contrast to [1, 2], such a relationship is characteristic only for a comparatively young object, and with greater /17
γ: $\gamma = 2$-3 (Figure 3). The latter results indicates that the energy spectra of the

electrons in nonstationary sources can not differ from the typical (for more details see for example, [11]).

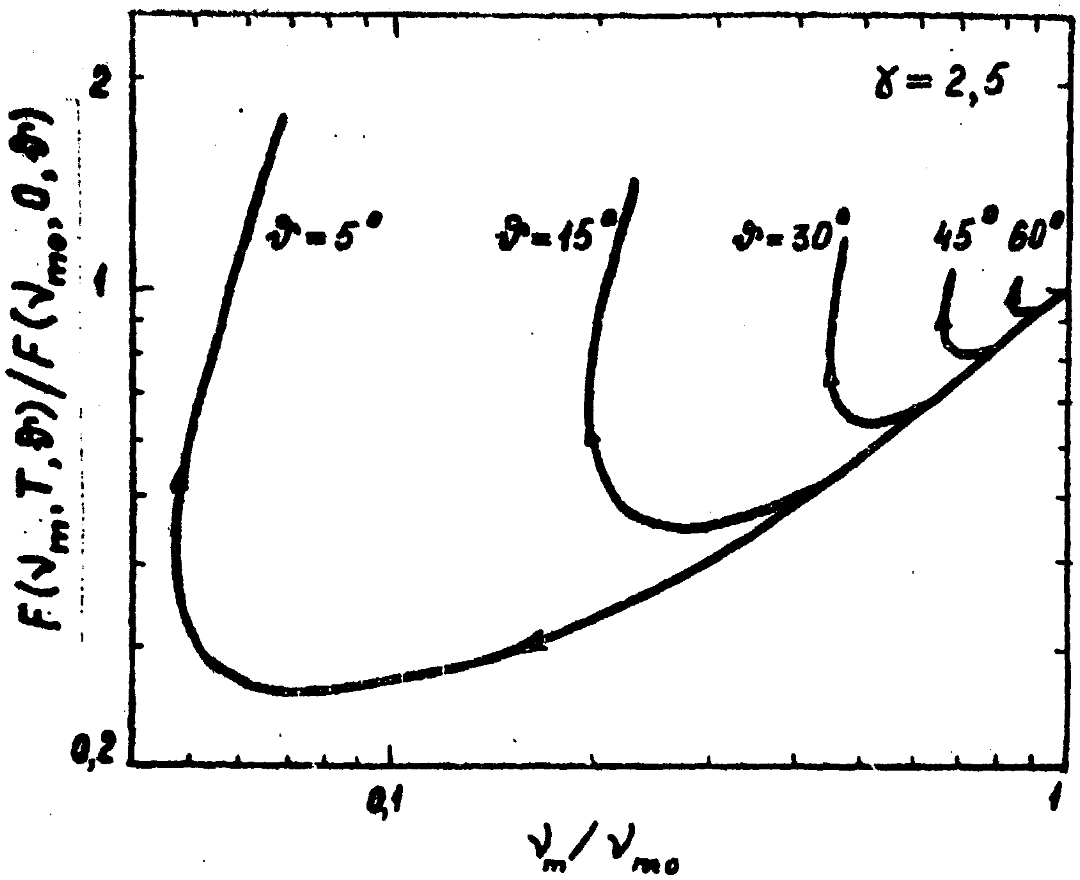

Figure 3. Evolution of the Maximum of Flux Density Spectrum and its Frequency ν_m/ν_{mo} for Fixed Angles of Observation ϑ with a Change in the Observation Time T from T=0 to T=cos ϑ (indicated by the arrow). With $\tau_n = \tau_0$ at the Moment T=cos ϑ the Flux at All Frequencies Theoretically Drops Sharply (not shown in the figure) Due to the Interception of the Evolving Electron Distribution Function, However Practically this Must Occur During a Certain Finite Time.

3. Flux variations (in the form of a narrow slash) from the jet in the examined model are a comparatively narrow-band process in relation to ν_{mo}, while $T < \cos\vartheta$ (Figure 4). It is not excluded that precisely this effect determines the difficulty

in searching for a correlation between flashes in the mm-and cm-ranges for certain objects.

4. Diversity in the time variations of the flux F_ν and the broad range of characteristic times τ of change in F_ν (from several hours to several years) [12] are usually explained by the superposition of emission from several clouds or several mechanisms. In the given case, they can be formally explained also by the difference in the beginning distances z_0, angles of observation ϑ of the clouds, and frequencies ν/ν_{m0} (Figure 4). Here, the indicated range can be completely covered, since $\tau \lessapprox \tau_{**}$, where $\tau_{**} = z_0 \cdot \cos\vartheta/c$ with $z_n = z_0$ (see Figure 2 for SW). In addition, additional analysis demonstrates that if z_n is sufficiently small as compared to z_0, then one cloud can yield up to three emission flashes, whereupon two strong flashes fall within the RW ($T > \cos\vartheta$), and are traced synchronously in a broader frequency range than the first governed by the SW ($T \lessapprox \cos\vartheta$).

5. Different types of spectra of variable sources (see for example, [12]) can be explained by the various combinations of nonstationary spectra of one or several clouds with spectrum of the stationary component (Figure 5). Qualitatively, the spectrum in Figure 5 is similar to the spectrum computed in [2], but only in the beginning stage of evolution.

6. Boundaries of Model Applicability /18

It is evident that the real conditions in certain sources can significantly differ from the model assumptions. First of all this refers to the structure of the magnetic field, that with sufficiently large z/z_0 a fortiori differs from the radial, being most likely, dipole or more complex. In addition, in this region the correlation between energy of the magnetic field and electrons can become

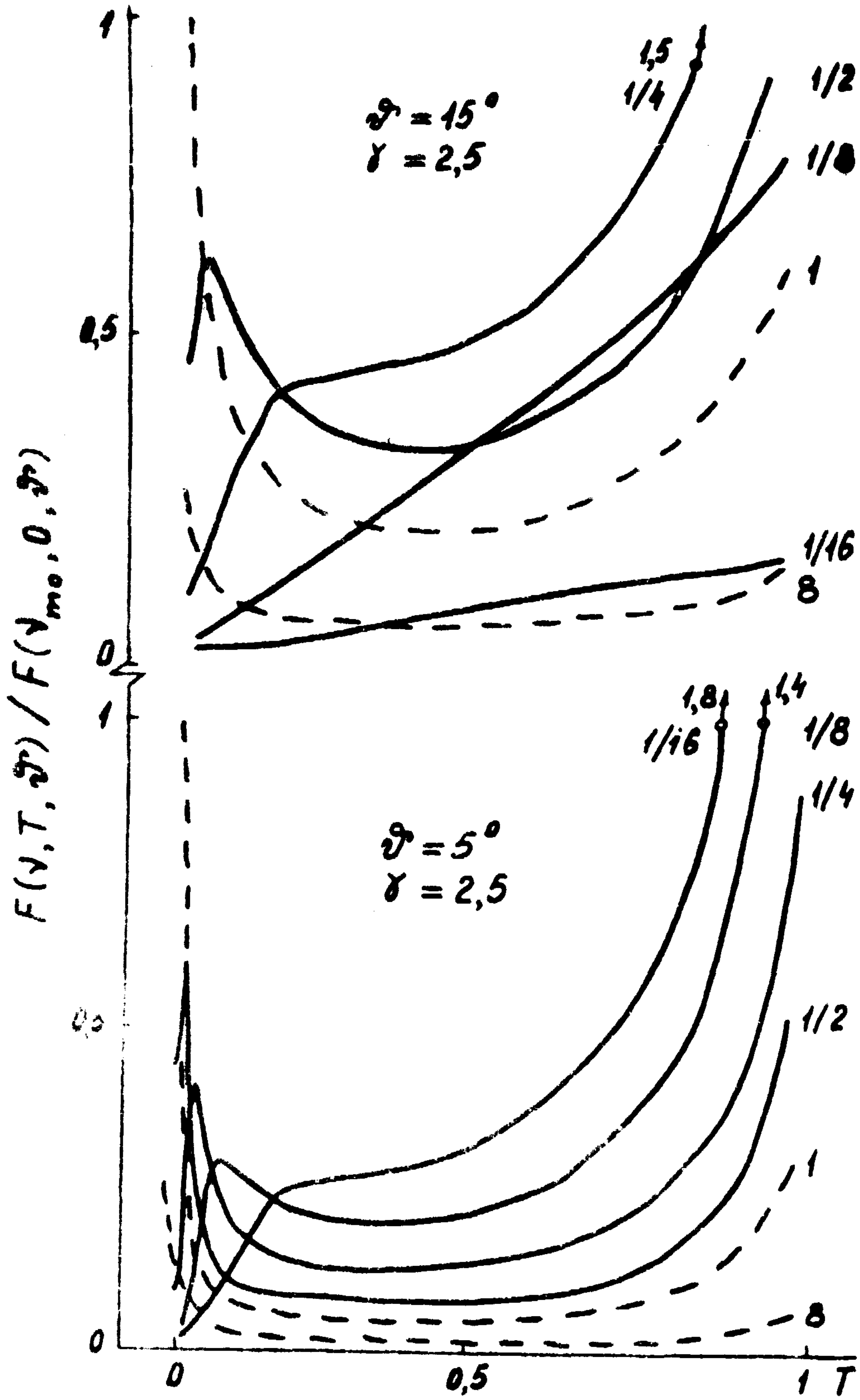

Figure 4. Time Evolution of Flux Density at Fixed Frequencies ν/ν_{mo} for Two Observation Angles ϑ and $\tau_0 = \tau_0$ (extinction of the cloud at moment $T=\cos\vartheta$ is not shown). The numbers on the curves give the values ν/ν_{mo}.

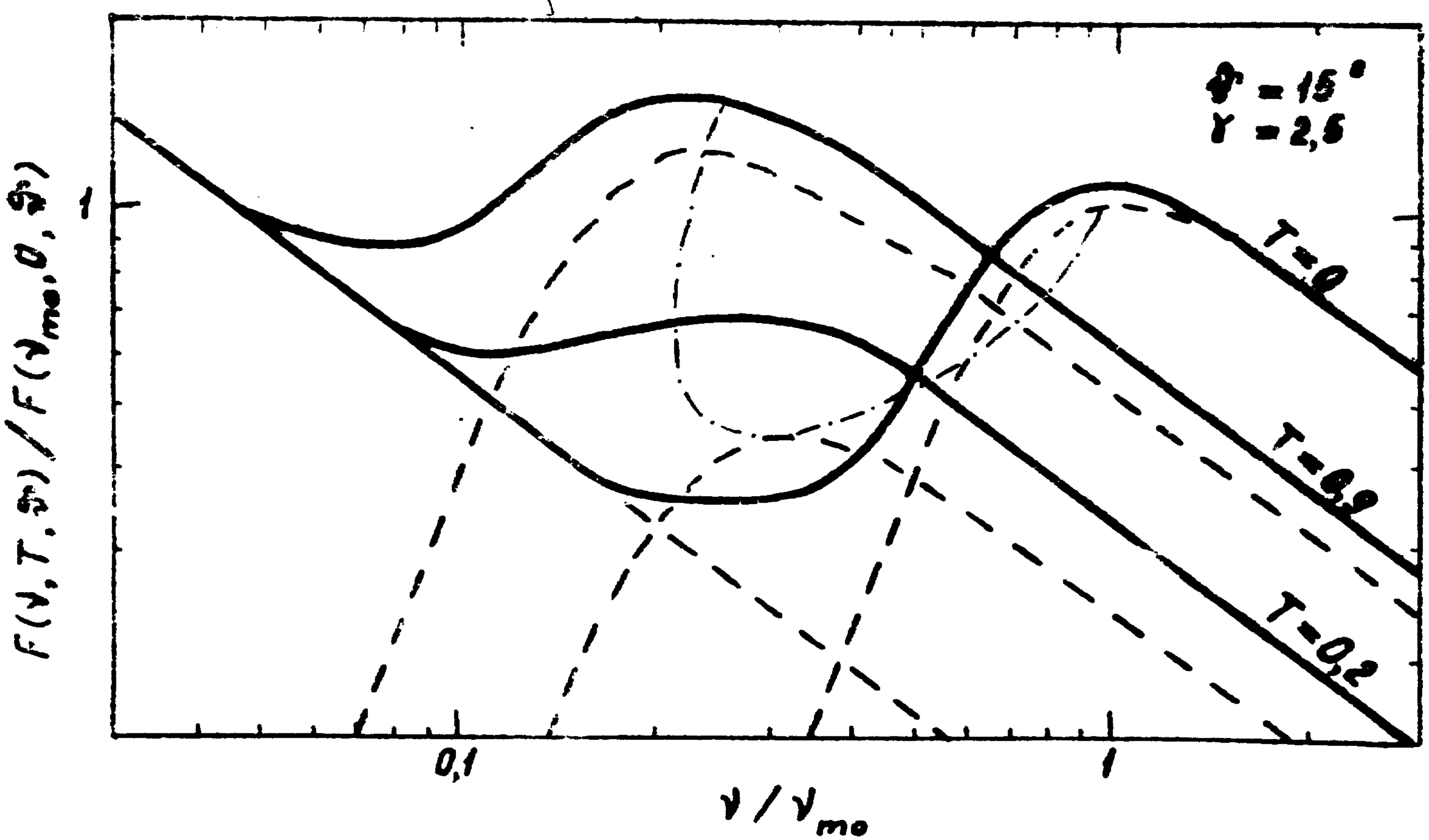

Figure 5. One of the Possible Combinations of the Calculated Cloud Spectrum (γ =2.5, ϑ=15°) with spectrum of component constant (for example, nuclei with the same γ) gives the typical spectrum of the variable source.

different, and as a result a significant chaotic field component appears. In another limit case, with sufficiently small τ/τ_0, the magnetic field can be intensified so much that the Compton losses will dominate. Thus, even if the model is completely applicable to the environs of the "birth site" of the cloud, certain conditions can be violated at a sufficient distance from it.

Fortunately, there are several circumstances, thanks to which these violations either do not affect the applicability of the model, or can be easily considered by introducing the corresponding corrections directly into the final results. For simplicity we will show this in the example of a jet. In fact, the noted deviations from the model do not "succeed" in affecting the result, if they are spatially localized outside the region $\tau_n \ll \tau \ll \tau_0/\sin\vartheta$, since the cloud is extinguished for the observer as soon as it goes beyond the limits of this region (the electrons moving in the region $\tau > \tau_0/\sin\vartheta$ "do not shine" in the direction of the observer, since their pitch angles have evolved to values lower than ϑ, while the electrons with $\tau < \tau_n$ are absorbed by the nucleus). If the region of applicability of the model is narrower than this region, then, after assigning the maximum spatial environs $\Delta\rho_\beta$ and $\Delta\rho_d$ of points β and d respectively (see Figure 2), in which the difference of conditions from the model is significant, with the help of (11) we immediately obtain the corresponding time intervals ΔT_β and ΔT_d at /19
which the calculated evolution of cloud emission should be replaced by a new one. The new emission at these, and the superposition of it with the model in the subsequent time segments will yield a corrected pattern of evolution. The thus corrected model can be the foundation for other models that take into consideration the specific nature of specific sources.

7. Conclusion

The central problem for any model undoubtedly is the clarification of the correspondence of it to actuality, since it is known that the "viability" of many models of the same phenomenon is often explained by the relatively free variation of certain parameters and the insufficient accuracy of the measurements. For the given model this was partially illustrated above, and as an example of the difficulties in comparison with observation we also note that the observed time relationship of the variable component spectrum, as a rule, is ambiguous due to the difficulties in isolating "background" components from the measured source spectrum, especially for a multiple-component object. Therefore it is better to use the coincidence of certain model and observed laws only as signs from which one should select the suspected sources.

An important further task can be the conducting of complex (spectral and interferometric) studies of the selected sources on a special program in order to simultaneously obtain their evolutionary spatial and spectral characteristics. In this case one should classify with the main criteria for applicability of the model of the studied source: 1) observed evolution α depending on $F_m \propto \nu_m^{\alpha}$ close to that shown in Figure 3; 2) change in the direction of component movement to the opposite or /20
a drastic extinguishing of it; 3) monotonic change in angular dimensions of the cloud and its angular separation with the nucleus in accordance with (27), (11) and (34). The importance of the complex approach is evident here. Such regular measurements of the object, for which the model is correct, will permit an evaluation of many of its parameters with the help of (26)-(34) and (11), and the obtaining of the scale of the source and its environs in absolute units, as well as the distance to it.

There are grounds to hope that despite the fact that the model modifications that are further possible can alter some of its characteristics (it is important, for example, to spread the model to other configurations of the magnetic field), the "fundamentality" of the parameter τ_0 and the possibility of obtaining it from the observations must be preserved.

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